9A.3 IMPACT OF PHYSICAL INITIALIZATION ON THE NAVY OPERATIONAL GLOBAL ATMOSPHERIC PREDICTION SYSTEM (NOGAPS)

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## 1. INTRODUCTION

A goal of the many numerical weather prediction centers is to improve the definition of the initial state and forecasts within the tropics. The difficulty of this problem and its resolution should not be understated. The tropics comprise about 50 percent of the surface area of the Earth and are very poorly sampled with respect to the middle latitude land areas. This is partially due to the fact that most of the tropics is ocean and the island stations are often far apart leaving wide gaps in the tropics with poor sampling in the vertical. Therefore, every piece of data is uniquely important due to its elevated level of importance in the analysis system.

Physical or diabatic initialization is an attempt to improve the analysis of the basic state variables by using nonconventional data like rainrates, outgoing longwave radiation or condensation heating rates derived from rainrates. Davidson and Puri (1992), as well as Mathur (1995) and Kasahara et al. (1994) among others, have examined techniques ranging from the use of satellite radiometric imagery data to Newtonian relaxation in order to improve the divergent circulation, the description of the moisture variable and to reduce model 'spin up' of the hydrologic cycle. Krishnamurti et al. (1994) examined a month of continuous physical initialization cases and found a decidedly positive impact on the short-range forecast of convective precipitation. They noted that tropical disturbances were much better forecast due to the modified environment associated with them.

The experiments with the Navy Operational Global Atmospheric Prediction System (NOGAPS, Hogan and Rosmond, 1991) global model is an attempt to examine the effect physical initialization can have in an operational environment. The physical initialization procedure has been added to the update cycle that was run at T-79 resolution. The physical initialization was done as the global model integrates to provide the 6 hour forecast (first guess) for the multivariate optimum interpolation analysis (Goerss and Phoebus, 1992).

## 2. PHYSICAL INITIALIZATION PROCEDURE

The analysis of the moisture variable is a very difficult aspect of data assimilation. Due to the high variability of moisture in the horizontal and lack of high quality observations, the moisture analysis is generally considered less accurate than the analysis of other meteorological state variables. One of the data types used for the moisture analysis (over the oceans) is the SSM/I integrated precipitable water. Therefore, a plausible assumption is that the amount of moisture in the atmospheric column is fairly well observed and perhaps needs only be partitioned in such a way that the convective parameterization can accurately produce the same rainrate as observed. The convective parameterization in the NOGAPS forecast model is of the relaxed Arakawa-Schubert (RAS) type (see Moorthi and Suarez, 1992).

Figure 1 illustrates how well the current system (control) reproduces the observed rainrates for an average day. The control rainfall for each gridpoint in the tropics (within +/- 35 degrees latitude) is plotted

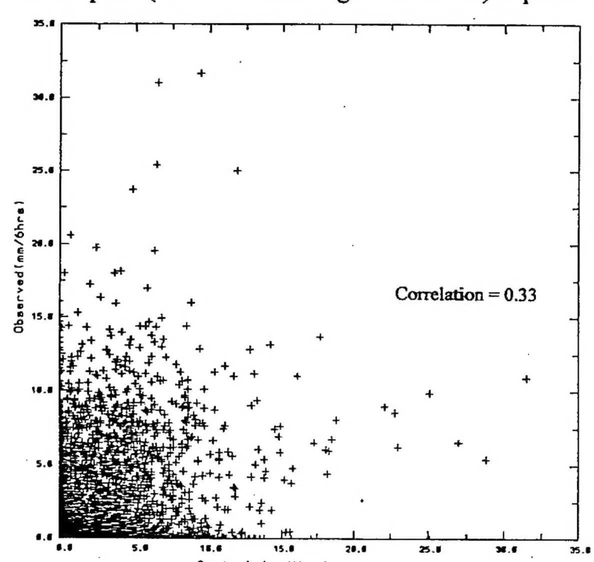


**Figure 1.** Scatter plot matching the control experiment assimilation accumulated rainfall with the observed rainrates for 23 Aug. 1993 at 06 UTC. Units are mm/6 hrs. The correlation is 0.33.

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against the observed amount. The control is the 6 hour accumulated rainfall from the NOGAPS update cycle and the observed is a rainrate analysis that is composed of SSM/I rainrate observations and outgoing longwave radiation (OLR)-derived rainrates.

The observed rainfall coverage is considered accurate; however, the actual amplitude information is somewhat suspect. The observed rainrate analysis captures the areas of high precipitation and appears to adequately resolve the precipitation/no precipitation threshold. The correlation of 0.33 between the observed and control rainfall is rather poor, yet very understandable given the nature of tropical convection and precipitation coupled with the lack of observations.

An iterative approach has been adopted to repartition the moisture in the vertical so that the model can reproduce or approach the observed rainrate amount at each model timestep. This provides a more accurate first guess field for the next multivariate optimum interpolation analysis due to this forcing. The moisture in the column was adjusted by adding a relative humidity perturbation, linear in pressure, to the original relative humidity. This procedure was done within the tropics at every gridpoint. The increase or decrease in latent heating acts to modify the vertical motion, divergence and thermal profile in a consistent and balanced manner throughout the tropics. Figure 2 shows the level of reproducibility the model's convective parameterization can obtain with the physical initialization procedure. A correlation of 0.88 with the observed rainrate is a dramatic improvement for this same period as compared to Figure 1. It should be noted that the correlation is remarkably good above 5.0 mm/6 hrs which is very desirable; however, the threshold precipitation (< 5 mm/6 hrs) is difficult to match. This case is fairly representative of the period examined.

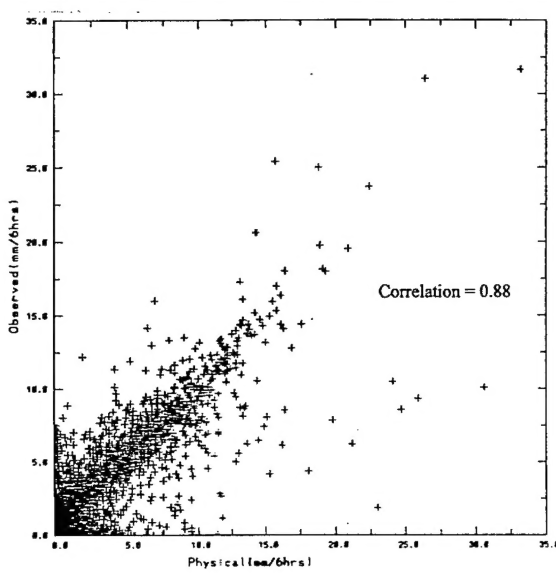


**Figure 2.** Scatter plot matching the physical experiment assimilation accumulated rainfall with the observed rainrates for 23 Aug. 1993 at 06 UTC. Units are mm/6 hrs. The correlation is 0.88.

## 3. DESCRIPTION OF EXPERIMENTS

The two week period beginning 23 August 1993 and ending 6 September 1993 has been examined to evaluate the ability of the physical initialization procedure to reproduce the observed rain within the NOGAPS update cycle. This provides a group of 57 consecutive 6 hour periods that should illustrate the daily and diurnal variability of some tropical features. At each synoptic time (00,06,12,18 UTC), the observed rainrates from -6 hrs are used to match the model convective precipitation at each timestep. This is necessary due to the limitations of the operational environment. In fact, the rainrate observations may exist at the actual analysis time so that a time interpolation of the observed rainrates, which would be considered a positive attribute, could be done. However, it was assumed not possible for this first set of experiments. A three day spin up of the physical initialization experiment was performed so that the two week period would be more consistent between experiments. No other changes to the NOGAPS forecast cycle were made for this set of experiments.

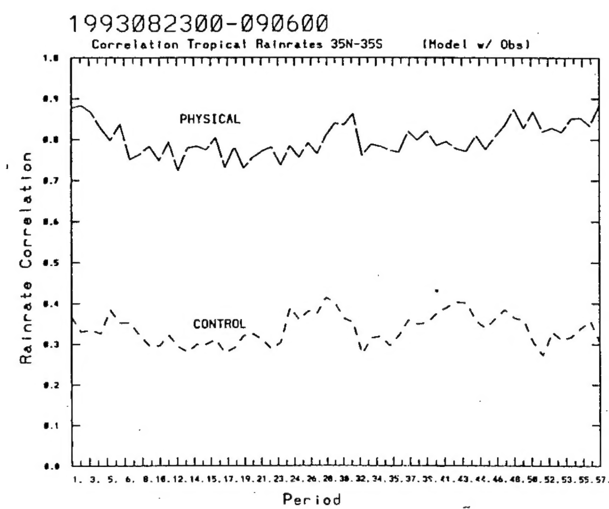


**Figure 3.** Correlation of the control and physical experiment tropical (within +/- 35° latitude) rainfall with the observed rainrates every 6 hrs. for the period 23 Aug. 1993 at 00 UTC to 6 Sept. 1993 at 00 UTC.

## 4. RESULTS AND DISCUSSION

An adequate evaluation of the physical initialization procedure should not be left solely to verifying precipitation amounts, but it is a good place to start. Figure 3 shows the tropical rainrate correlations for the control and physical (physically initialized) cases with the observed rainrates. The physical experiment exemplifies an improved ability to match the 6 hour rain amounts. The reproducibility of the observed values implies that relatively small changes in the moisture profile can have a dramatic impact on how well the convective parameterization performs and verifies. The average improvement in the correlation of about 0.5 illustrates that much of the deficiency in the tropical analysis is due to the poor definition of the moisture variable. However, the motion and mass fields in the control are suffering from the lack of or inadequate feedback from the convective parameterization and its forced secondary circulation.

The adjustments in the tropics due to physical initialization rapidly make their way into the middle latitudes. Figure 4 illustrates the difference between the control and physical 500 hPa geopotential height analysis for 1 September 1993 at 12 UTC. The Southern Hemisphere winter circulation is more closely coupled to the convection in the tropics. Thus, the heat and moisture transport into the middle latitudes appears more robust. The amount of difference between the height fields is not very large; however, the areas where differences can be seen are locations with large baroclinic instability and cyclone activity. By day two of the forecast (not shown) these small initial differences grow into larger, more organized patterns that can dramatically affect forecast skill. This was seen throughout the experiment period. Therefore, physical initialization (or the lack thereof) within the tropics can rapidly influence skill in the middle latitudes.

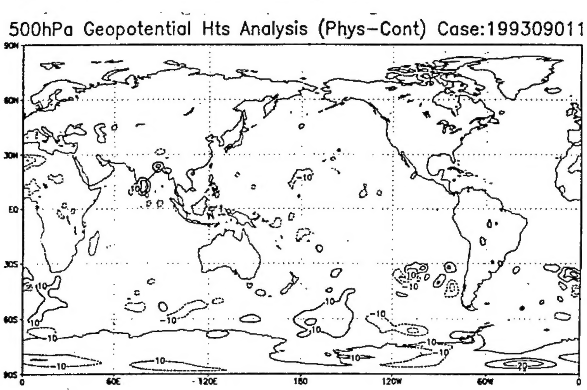


**Figure 4.** 500 hPa geopotential height analysis difference (physical-control) for 1 Sept. 1993 at 12 UTC. Contoured at 10 m. with the dashed line implying negative values.

The added accuracy, better location and intensity of convective precipitation have led to an improvement in the NOGAPS assimilation rainrates as verified against observations from satellite. The feedback from the RAS scheme to the tropical circulation appears to improve the first guess for the multivariate optimum interpolation analysis; however, certain geographic regions benefit much more than others.

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